FOR ERRATA

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THE FOLLOWING PAGES ARE CHANGES

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ERRATA TO: Kennedy, R., and Graybiel, A. Symptomatology during prolonged exposure in a constantly rotating environment at a velocity of one revolution per minute. BuMed Project MR005.13-6001 Subtask 1 Report No. 62 and NASA Order No. R-1: Pensacola, Fla.: Naval School of Aviation Medicine, 8 September 1961.

1). Page 14.

Table XIII. Insert RL and JL in heading.

	RL					JL				
	AM	PM	AM	PM	Post	AM	PM	AM	PM	Post

2). Page 16.

Table XIV. Change RP to RB.

3). Page 16.

Table XV. Insert column headings.

	AG				RB			
	Open		Closed		Open		Closed	
	R	L	R	L	R	L	R	L

4). Page 6.

2nd paragraph, 3rd line change "(PR)" to "(DK)".

SYMPTOMATOLOGY DURING PROLONGED EXPOSURE IN A CONSTANTLY ROTATING ENVIRONMENT AT A VELOCITY OF ONE REVOLUTION PER MINUTE*

By

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AND

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Research Report

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Bureau of Medicine and Surgery
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SUMMARY PAGE

THE PROBLEM

It has been demonstrated in previous studies that prolonged exposure to constant velocities between 1.7 RPM and 10.0 RPM produce a constellation of symptoms collectively termed canal sickness. Under similar conditions, the diversity and severity of the manifestations were directly related to the angular velocity of the room. Since even at 1.7 RPM some symptoms were observed, one RPM was chosen as the rotation velocity and subjects were selected to include those with high levels of susceptibility to canal sickness and motion sickness.

FINDINGS

The results show that exposure under the conditions of this experiment to a constantly rotating environment at one RPM does not handicap the performance of persons, including those with far greater than average susceptibility to canal sickness.

ACKNOWLEDGMENTS

We are deeply grateful to the subjects, Doctor R. G. Bartlett, Jr., Ensign R. Lattimore, J. Lowder, K. W. Denzer, R. G. Futch, D.J. Kolenda, and P. Residine. We also appreciate the able assistance of the Acceleration Unit staff, particularly Miss Mary Norsworthy, Lieutenant J. L. Mason, and Chiefs F. Prouty and R. Garlock.

INTRODUCTION

Previous reports from this laboratory (1, 3) have described the symptomatology in men exposed over prolonged periods to constant angular velocities between 1.7 RPM and 10.0 RPM. The symptoms had their genesis in the semicircular canals which were subjected to unusual patterns of stimulation due to Coriolis accelerations generated by rotations of the head out of the plane of rotation of the room. The subjects experienced visual and postural illusions, had difficulty in walking, and manifested a wide variety of symptoms termed canal sickness. Under similar conditions, the diversity and severity of the manifestation were directly related to the angular velocity of the room. Even at 1.7 RPM or 2.0 RPM visual illusions were perceived and mild symptoms of canal sickness were experienced by the subjects until they adapted to the rotating environment. The present investigation was considered to be a necessary extension of past studies to define the angular velocity of the rotating environment which would not cause disturbing symptoms.

Pilot experiments indicated that the great majority of unselected subjects would be symptom free rotating at one revolution per minute. Accordingly, systematic observations were carried out at this angular velocity on subjects ranging from low to very high susceptibility to canal sickness.

EXPERIMENT I

SUBJECTS

The clinical findings of the four subjects are summarized in Table I. None had any history or complaints referable to the sensory organs of the inner ears and medical examination revealed no definite abnormalities.

APPARATUS AND PROCEDURE

The Slow Rotation Room (SRR), described elsewhere in detail (3), consisted of a nearly circular enclosure about 15 feet in diameter and 7 feet high, with accommodations for living and with provisions for carrying out the several experimental tests and procedures. The angular velocity of the room varied little ($\pm$ 2.5%) except with the onset and cessation of rotation. At one RPM the centripetal force at the periphery was 0.002 G, but the effective stimulus was an inertial torque due to Coriolis accelerations of different magnitudes generated around the circumference of the canals (5). Thus, the participants were "stimulated" not only during experimenter-paced body (head) movements but also incidentally to carrying out various necessary activities. The stimulus could be avoided by "fixing" the head.

Table I

Clinical Findings on Four Subjects Within the Usual Range of Susceptibility to Canal Sickness

Subject	Sex	Age	General Fitness	Otoscopic Exam	Hearing	Threshold Caloric Test (°C) R	L	Susceptibility To Motion Sickness*	Susceptibility To Canal Sickness (SRR)
RD	M	17	Good	N	N	33.7	34.8	Below Avg.	Below Avg.
PR	M	21	Good	N	N	34.9	35.0	Below Avg.	Average
RF	M	21	Good	N	N	----	----	Average	Average
DK	M	19	Good	N	N	36.0	35.7	Above Avg.	Above Avg.

*Based on a questionnaire covering past experience.

The following tests and performance measures were used:

1. Oculogyral Illusions

The possibility existed for perceiving three types of the oculogyral illusion (OGI), depending on the circumstances under which the stimulus to the canals took place, namely, 1) rotation of the subject's head out of the plane of rotation of the room (Coriolis illusion), 2) stimulation of the horizontal canals with head fixed during onset and cessation of rotation on the centrifuge (acceleration OGI) (2), and 3) rotation of the head in the frontal plane after cessation of rotation of room in the case of a subject previously adapted to rotation (post-adaptation OGI) (4).

For the perception of the Coriolis illusion the subject viewed a luminous target in the dark. The target consisted of a box approximately 7 inches square with holes along its edges illuminated from within, creating a three-dimensional object. It was placed at eye level in front of the subject at a distance of 6 feet. The subject's head was fixed to a swivel by means of a biting board which restricted rotation to an arc of 45 degrees in the frontal plane. The rotation of the head was carried out in about 1.25 seconds with the aid of a metronome. On command, the subject rotated the head toward the left shoulder and, after a delay of ten seconds, returned to the upright. Subjects reported on the distance, direction, and velocity of the apparent movement of the target while moving the head. Distance was judged in feet and inches. All the people who served as subjects had previously seen the illusion at higher rates of rotation.

The above procedure was carried out not only during rotation but also prior to and shortly after the cessation of rotation. Prior to rotation (control conditions) the subject, with rare exceptions, reported "no movement." These exceptions may have been the result of slight parallax due to the change in relation of the line of regard to the three-dimensional target. Perception of an illusion after the conclusion of a prolonged run was regarded as a post-adaptation phenomenon.

2. Modified Romberg

The subject with eyes closed was required to stand first on one foot then the other for thirty seconds. If the duration was less than ten seconds, the best score on three trials was used. The subject was also given a qualitative rating on the following point scale: 1 point, slight body sway, no foot movement; 2 points, definite sway of small amount, no foot movement; 3 points, substantial sway but no foot movement; 4 points, substantial body sway and foot is moved; 5 points, substantial body sway and other foot was put down to prevent falling.

This test was carried out before rotation and after cessation of rotation at the end of the run.

3. Walking

The subject was required to take six heel-to-toe steps from the periphery of the room toward the center of rotation, then return. This was repeated with eyes closed. The subject was scored in terms of his deviation from his own norm on this task when the wheel was stationary (1 slight, 2 moderate, 3 marked deviation).

4. Dial Test

This was at once a stressor and performance test. The task involved reading and setting five dials so placed that the subject while seated was required to rotate his head (and body) through different complex arcs in order to view the dial and adjust the indicator. The dials were always "set" in the same sequence, one through five in response to recorded instructions. The instruction, after alerting the subjects, gave the number to which the first dial indicator should be set and after a pause of six seconds, the second number was given, and so on for all five dials. This constituted one sequence. The second sequence followed the first after a pause of six seconds. There were 20 sequences of 5 settings for a total of 100.

5. Mathematics Test

This was a simple test of arithmetic computation. It consisted of 827 items, alternating addition, subtraction, multiplication, and division. The subject was instructed to work both for speed and accuracy. He started on command, and the experimenter started a stop watch. At the end of fifteen minutes, the test was terminated. The score was the number correct and per cent correct.

6. Dart Throwing

A Sportcraft Dartboard and five Unicorn darts were used. The dart board was circular (18 inches in diameter) and divided into six concentric rings about a bullseye, 1.5 inches in diameter. No particular directions regarding throwing were given except that the subject was to make the highest possible score and use the same procedure throughout. The board was mounted on the wall, and the subject stood 9 feet from the door, throwing past the center post and one of the main centrifuge braces. The score for each series of throws was the sum of the points indicated on the board, the bullseye counted 100 and succeeding rings as follows: 80, 60, 40, 30, 20, 10.

EXPERIMENTAL ROUTINE

This began at 1:00 P.M. on the first day and ended at 3:00 P.M. on the third day. Control measurements were made prior to the onset of rotation. A final check was made on the fitness of the subjects and electrocardiograms obtained. The room was set in

motion at 2:10 P.M., and the tests repeated. These ended with the dial test immediately after which an electrocardiogram was obtained, and the subject filled out a questionnaire dealing with canal sickness; the experimenter added his comments on the objective symptomatology. In addition, the experimenter kept a log of all significant events. The experimental routine was repeated at 9:30 A.M. and 4:00 P.M. on the second day and at 9:30 A.M. and 1:00 P.M. on the third day. On cessation of rotation at 2:45 P.M., the subjects, with head fixed, viewed the target in the dark to observe the oculogyral illusion. After the room was stationary, each subject remained with head fixed until it was his turn to serve as subject for the final series of experimental tests. Difficulty in controlling the air conditioning the first day resulted in the room temperature rising to 84 degrees F. This was a factor tending not only to increase susceptibility to canal sickness but also to lead directly to unpleasant feelings of warmth and drowsiness .

RESULTS AND DISCUSSION

The results on the oculogyral illusion are summarized in Table II. It is necessary to interpret the findings with regard to the visual illusions in the light of results obtained at higher levels of stimulation (4). Characteristically, the Coriolis illusion is readily perceived at the beginning of the experimental period after which adaptation occurs, resulting eventually in a great reduction or disappearance of this illusion. After cessation of rotation, a post-adaptation illusion may be observed, although a Coriolis acceleration is not generated, only an angular acceleration. Exceptionally, the post-adaptation oculogyral illusion may be more prominent than the Coriolis illusion.

Table II

Perception of Apparent Movement (in Inches) by Four Subjects During and After Rotation at 1 RPM

	Trial 1				Trial 2				Trial 3				After Rotation			
Rotation Head	RD	PR	RF	DK	RD	PR	RF	DK	RD	PR	RF	DK	RD	PR	RF	DK
Upright to 45° R	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0	0	0
45° R to Upright	0	0	0	0	0	0	0	0	0	1	0	0	0.75	0	6	0.5
Upright to 45° L	0	0	0	0	0	0	0	0	0	0	0	0	0.75	0	6	0
45° L to Upright	0	1	1	0	0	0	0	0	0	1	0	0	0.75	0	0	0.5

In the present experiment two of the four subjects reported "apparent movement" while carrying out the test for the Coriolis illusion. RF saw the apparent movement only once. PR saw the apparent movement on three occasions, but the first was on the afternoon of the second day by which time adaptation effects should have decreased the likelihood of its perception. Moreover, he did not perceive a post-adaptation oculogyral illusion. Even assuming that the two subjects perceived a Coriolis illusion in the "threshold range," the practical significance was nil in terms of interfering with carrying out activities.

Three subjects reported a post-adaptation oculogyral illusion. Although RF reported an apparent movement only on rotation leftward, this is not unusual, and the magnitude of the movement, 6 inches, was far greater than might be perceived under control conditions. RD consistently saw apparent movement of small magnitude on all four trials. He was just as consistent in never perceiving it while the room was rotating. DK saw very little movement on two trials, both of which involved return head movements to the upright.

Table III presents the scores obtained on a modified Romberg test before and after rotation. The fall off in performance is a post-adaptation phenomenon regularly observed.

Table III

Scores on Four Subjects Before and After Rotation on the Modified Romberg Test*

		Before		After	
		Qualitative Score	Time	Qualitative Score	Time
RD	Right	3	30	5	16
	Left	3	30	5	27
PR	Right	3	30	5	9
	Left	2	30	5	21
RF	Right	2	30	4	30
	Left	2	30	5	25
DK	Right	3	30	5	13
	Left	2	30	5	20

*See Text.

No attempt was made to measure postural illusions per se, although walking heel-to-toe with eyes closed reflected the effect of Coriolis accelerations on postural mechanisms. The scores (Table IV) show that all of the subjects experienced difficulty at first but adaptation was complete in each instance. Post-adaptation difficulty was manifested by three subjects. There was a strong relationship between the difficulty experienced in walking with eyes closed and high threshold levels as measured by caloric stimulation.

Table IV

Scores Made by Four Subjects on Heel-To-Toe Walking Test

	RD		PR		RF		DK	
Eyes	Open	Closed	Open	Closed	Open	Closed	Open	Closed
Before Rot.	0	0	0	0	0	0	0	0
Rot. 1	0	1	0	1	0	3	0	1
Rot. 2	0	0	0	1	0	2	0	0.5
Rot. 3	0	0	0	1	0	1	0	0.5
Rot. 4	0	0	0	0	0	0.5	0	0
Rot. 5	0	0	0	0	0	0	0	0
After Rot.	0	0.5	0	1	0	2	0	0

Table V contains the scores obtained on the Mathematics test. It may be seen that while the number correct increases with time, the per cent correct does not change appreciably. If the effects of rotation were responsible, the performance decrement would be reflected in a lowering of the per cent correct. The increase in number correct is probably a function of learning. It would seem, therefore, that there is no reduction of performance on the Mathematics test as a result of rotation and that the variable operant is learning.

Table V

Scores Made by Four Subjects on a Mathematics Test
(Number Correct and Per Cent Correct)

	RD		PR		RF		DK	
	No.	%	No.	%	No.	%	No.	%
Before Rot.	151	93	x	x	290	98	268	94
Rot. 1	222	98	270	90	361	97	261	95
Rot. 2	239	95	359	96	414	98	390	98
Rot. 3	274	97	422	96	423	97	391	97
Rot. 4	290	95	509	97	489	98	420	96
Rot. 5	273	92	539	98	510	98	411	96
After Rot.	274	90	410	97	494	99	445	95

x Not done.

The scores on the dart test as seen in Table VI are interesting in that, with the onset of rotation, a significant lowering of the score did not occur, yet after cessation of rotation the scores were lower. In previous studies at the higher RPM, gross changes did occur in dart test scores. However, with practice, the subjects learned to compensate for the rotation and ultimately produced a score comparable to their pre-test scores. In the present experiment, the angular velocity was such that while there was no need to compensate for the effects of rotation, yet, adaptation to rotation was sufficient to cause a post-adaptation phenomenon.

The syndrome of canal sickness was not observed, as may be seen in Table VII. The most stressful periods were during the dial test which all subjects completed without difficulty. This test gave rise to symptoms in only one subject (PR) and then only during the first session when he felt "a little warm and dizzy" at the beginning of the test.

An analysis of the electrocardiograms revealed no significant changes, although the tracing of RF exhibited slightly faster heart rates than usual and very slight variations in the level of S-T junction and the height of T waves.

Table VI

Scores Made by Four Subjects on a Dart Throwing Test

	RD	PR	RF	DK
Before Rot.	410	500	410	310
Rot. 1	410	381	381	340
Rot. 2	410	340	400	240
Rot. 3	400	400	420	320
Rot. 4	410	390	320	270
Rot. 5	370	270	420	300
After Rot.	360	310	340	150

It may be concluded that the subjects in this experiment exposed for a period of fifty hours in a closed room rotating at one RPM had no complaints and that the Coriolis accelerations were below threshold for most of the manifestations observed at higher levels of stimulation. Indeed, the only test revealing any handicap was walking heel-to-toe with eyes closed. Eventually, they adapted even to this unusual task. Rotation at one RPM was at or below a perceptual threshold for the Coriolis illusion. Post-ataptation phenomena provided additional evidence that adaptation to the Coriolis stimulus occurred during exposure in the constantly rotating environment.

EXPERIMENT II

From the results of the first experiment it was learned that subjects within the usual range of susceptibility to motion sickness or canal sickness were aware of rotation at one RPM only when walking heel-to-toe with eyes closed. That this stimulus level was not far below "threshold" was indicated by the positive findings in previous studies at 1.7 and 2.0 RPM (3). Consequently, it was decided to maintain the same stimulus conditions in the second experiment but employ subjects with greater than usual susceptibility to canal sickness.

Table VII

Manifestations of Canal Sickness Following Dial Test

	RD						PR						RF						DK					
Day	1st PM	2nd AM	2nd PM	3rd AM	3rd PM	Post	1st PM	2nd AM	2nd PM	3rd AM	3rd PM	Post	1st PM	2nd AM	2nd PM	3rd AM	3rd PM	Post	1st PM	2nd AM	2nd PM	3rd AM	3rd PM	Post
Completed Dial Test	Yes	Yes	Yes	Yes	Yes	Yes	x	x	x	x	x	x	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
General Malaise	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sweating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nausea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Vomiting Episodes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apathy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hours Slept During Day	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Dizziness	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	1	0	0	0	0	3
Headache	1	0	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	1	1	1	0.5	0	0	1

Scoring: 0 - Asymptomatic; 1 - Slight, 2 - Moderate, 3- Marked.
x - Not Done.

SUBJECTS AND PROCEDURE

The two subjects in this experiment, JL and RL, 39 and 24 years of age, respectively, were gymnasium instructors in excellent health. In previous experiments both subjects had manifested far greater than usual susceptibility to visual illusions and canal sickness. Neither had any complaints, other than motion sickness,* referable to the sensory organs of the inner ear. JL had lost the sight of the right eye. Their thresholds to caloric stimulation were: JL, right 35.5, left 35.4; RL, right 34.8, left 35.0.

In addition to the experimental procedures of Experiment I, both subjects carried out vigorous calisthenics involving head movements on both experimental days. The duration of the experiment was shortened to thirty hours (two days and one night), and electrocardiograms were not obtained.

RESULTS AND DISCUSSION

As may be seen in Table VIII the results of the tests for the visual illusions were clear-cut. Neither subject perceived the Coriolis illusion but both perceived a post-adaptation oculogyral illusion of considerable magnitude. Also, both perceived a deceleration oculogyral illusion.

Table VIII

Perception of Apparent Movement (In Inches) By Two Subjects
During and After Rotation at 1 RPM

	Trial 1		Trial 2		Trial 3		After Rotation	
Rotation Head	RL	JL	RL	JL	RL	JL	RL	JL
Upright to 45° R	0	0	0	0	0	0	1	2
45° R to Upright	0	0	0	0	0	0	1	2
Upright to 45° L	0	0	0	0	0	0	8	6
45° L to Upright	0	0	0	0	0	0	8	6

* RL had been dropped from flight training for air sickness.

Table IX contains the scores on the Romberg test. The poor qualitative scores after rotation indicate unsteadiness and are again an example of post-adaptation phenomena.

Table IX

Scores on Two Subjects on the Modified Rombert Test Before and After Rotation

		Before		After	
		Qualitative Score	Time	Qualitative Score	Time
RL	Right	4	30	5	9
	Left	2	30	5	11
JL	Right	1	30	3	30
	Left	3	30	5	19

Walking heel-to-toe with eyes closed (Table X) was the only test procedure which yielded positive findings during rotation. The time course of adaptation is evident as is the increased difficulty after cessation of rotation. RL had very slight difficulty on the initial test with eyes open but considerable difficulty with eyes closed and did not fully adapt before the end of the run. JL had no difficulty with eyes open and only sight difficulty with eyes closed but adapted before the end of the run.

Table X

Scores Made by Two Subjects on Heel-To-Toe Walking Test

	RL		JL	
Eyes	Open	Closed	Open	Closed
Before Rotation	0	0	0	0
Rot. 1	0.5	3	0	1
Rot. 2	0	2	0	1
Rot. 3	0	1	0	0
After Rotation	0	2	0	1

Both subjects carried out the dial test without complaint, and the only symptom was moderate apathy following completion of the initial test.

The results of the Mathematics test (Table XI) and the dart test (Table XII) are similar to those obtained in the first experiment: 1) The per cent correct does not change appreciably, but the number correct does, thus indicating learning; 2) the scores on the dart test during rotation are fairly constant and the final score after rotation is generally lower, again giving evidence of post-adaptation phenomena.

Table XI

Scores Made by Two Subjects on a Mathematics Test
(Number Correct and Per Cent Correct)

	RL		JL	
	No.	%	No.	%
Before Rot.	523	98	215	96
Rot. 1	662	98	191	90
Rot. 2	658	98	206	84
Rot. 3	680	99	250	94
After Rot.	681	99	282	97

Table XIII contains a list of observations made at the conclusion of the dial test. With the exception of slight apathy at the conclusion of the first testing session, the subjects were clearly asymptomatic. The fact that the susceptible dyad reported fewer symptoms of canal sickness than the first experimental group may be due in part to the past experience of Group II. Both are physical fitness enthusiasts who are highly motivated and had previously reacted violently to the higher RPM. Therefore, a stimulus around threshold (as one RPM appears to be) may be judged by them to be no stimulus at all.

Table XII

Scores Made by Two Subjects on a Dart Throwing Test

	RL	JL
Before Rot.	360	470
Rot. 1	310	420
Rot. 2	380	430
Rot. 3	350	420
Rot. 4	360	460
After Rot.	340	380

Table XIII

Manifestations of Canal Sickness Following Dial Test

	AM	PM	AM	PM	Post	AM	PM	AM	PM	Post
Completed Dial Test	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
General Malaise	0	0	0	0	0	0	0	0	0	0
Sweating	0	0	0	0	0	0	0	0	0	0
Nausea	0	0	0	0	0	0	0	0	0	0
Vomiting Episodes	0	0	0	0	0	0	0	0	0	0
Apathy	2	0	0	0	0	2	0	0	0	0
Hours Slept During Day	0	0	0	0	0	0	0	0	0	0
Dizziness	0	0	0	0	0	0	0	0	0	0
Headache	0	0	0	0	0	0	0	0	0	0

EXPERIMENT III

SUBJECTS AND PROCEDURE

The two subjects participating in this experiment had life-long histories of motion sickness. RB, a man 34 years of age, had always enjoyed good general health except for occasional migraine headaches. He had never had any disease or disorder of the sensory organs of the inner ear. His threshold of sensitivity as measured by the caloric test was right, 35.5 and left, 35.0. During a previous exposure to rotation (6.0 RPM) in the SRR, he experienced nausea within a few minutes which was quickly followed by a severe vasodepressor collapse (3). The second subject, AG, 59 years of age, had always enjoyed good general health and never had any disease or disorder of the sensory organs of the inner ear. His threshold of sensitivity as measured by the caloric test was right, 34.7 and left, 34.8. During previous exposures to constant rotation in the SRR, a single head (body) movement at 10.0 RPM was sufficient to cause stomach awareness and three to five movements, nausea.

The experimental procedure described in Experiments I and II was modified and simplified, the attention being focused on the possibility of producing subjective symptoms by means of the dial test and other activities involving head movements. The run began at 8:30 A.M. and ended at 1:10 P.M. Tests for the visual illusions were carried out in the manner previously described at 8:30 A.M., 10:25 A.M., and 12:15 P.M. as well as before and after rotation.

RESULTS AND DISCUSSION

The results are summarized in Tables XIV through XVII. From Table XIV it is seen that both subjects perceived the Coriolis OGI. Initially, it was of small magnitude. After two hours of rotation RB perceived no illusion and AG was uncertain. Neither perceived the illusion on the third trial. Both viewed the target as the room stopped and received a strong deceleration illusion. When the test for the post-rotation illusion was given, AG was uncertain and RB reported slight movement.

In this experiment the modified Romberg was performed during rotation as well as before and after and was done with eyes open and closed. Neither had trouble with eyes open at any time. With eyes closed AG was quite steady prior to rotation but experienced some difficulty when the room was moving. RB experienced no difficulty during rotation, and the scores were not significantly different compared with the control.

Walking with eyes open appears to have presented no problem, but with eyes closed a gradual improvement is seen from the beginning of rotation to the end. Upon cessation of rotation about as much difficulty was experienced as at onset.

Table XIV

Perception of Apparent Movement (In Inches) By Two Subjects
During and After Rotation at 1 RPM

Rotation Head	Control AG	Control RB	Trial 1 AG	Trial 1 RB	Trial 2 AG	Trial 2 RB	Trial 3 AG	Trial 3 RP	After Rotation AG	After Rotation RB
Upright to 45° R	0	0	3	4	0*	0	0	0	0*	2
45° R to Upright	0	0	0	0	0*	0	0	0	0*	0
Upright to 45° L	0	0	4	4	0*	0	0	0	0*	3
45° L to Upright	0	0	5	2	0*	0	0	0	0*	3

*Uncertain

Table XV

Steadiness Test Eyes Opened and Closed

Before Rot.	1 30	1 30	2 30	2 30	1 30	1 30	5 16	4 30		
Rot. 1	1 30	1 30	5 22	2 30	1 30	1 30	4 30	4 30		
Rot.2	1 30	1 30	5 25	4 30	1 30	1 30	3 30	3 30		
Rot.3	1 30	1 30	4 30	4 30	1 30	1 30	3 30	4 30		
After Rot.	1 30	1 30	4 30	4 30	1 30	1 30	4 30	4 30		

Table XVI

Scores Made by Two Subjects on Heel-To-Toe Walking Test

	AG		RB	
	Open	Closed	Open	Closed
Before Rot.	0	0	0	0
Rot. 1	0	2	0	2
Rot. 2	0	0	0	1
Rot. 3	0	0	0	0
After Rot.	0	2	1	1

Table XVII

Manifestations of Canal Sickness Following Dial Test

	AG				RB			
	1	2	3	Post	1	2	3	Post
Completed Dial Test	Yes	Yes	Yes	x	Yes	Yes	Yes	x
General Malaise	1	0	0	1	1	0	0	1
Sweating	0	0	0	0	0	0	0	0
Nausea	0	0	0	0	0	0	0	0
Vomiting Episodes	0	0	0	0	0	0	0	0
Apathy	0	0	0	0	0	0	0	0
Yawning	1	0	0	0	3	3	3	0
Dizziness	0	0	0	0	0	0	0	0
Headache	1	0	0	1*	0	0	0	0

x Not done *Disappeared in 5 hours.

At the onset of rotation RB had slight malaise and AG a headache. The completion of the dial test did not aggravate these symptoms of canal sickness, but did produce a great deal of yawning. Later in the experiment when all subjective feelings of headache and malaise were gone, both subjects again experienced yawning while performing this dial test.

CONCLUSIONS

Following cessation of rotation, all subjects save one exhibited post-adaptation phenomena. The interesting observation was made that these phenomena may appear in the absence of any antecedent manifestation during rotation. This suggests, if it does not prove, that awareness of the effects of Coriolis stimulation on the part of the subject is not an essential factor in adaptation and that manifestations after cessation of Coriolis stimulation may be the first indication that adaptation had occurred.

It is concluded that exposure under the conditions of this experiment to a constantly rotating environment at one RPM does not handicap the performance of persons with far greater than average susceptibility to canal sickness. This has direct application to rotating environments such as those which might be experienced in orbiting vehicles caused to spin as a means of generating an artificial field force.

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Kennedy, R.
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SYMPTOMATOLOGY DURING PROLONGED EXPOSURE IN A CONSTANTLY ROTATING ENVIRONMENT AT A VELOCITY OF ONE REVOLUTION PER MINUTE. BuMed Project MR005.13-6001 Subtask 1, Report No. 62 and NASA Order No. R-1: Pensacola, Fla.: Naval School of Aviation Medicine, 8 September.

Eight subjects were systematically observed on certain tasks aboard the Pensacola Slow Rotation Room at a velocity of one RPM. Pilot experiments indicated the great majority of unselected subjects would be symptom free at this speed. Consequently, four subjects were selected whose susceptibility to canal sickness and motion sickness was far above average. The findings warranted the conclusion that under the conditions of this experiment, exposure to a constantly rotating environment at one RPM does not handicap the performance of persons with far greater than average susceptibility to canal sickness.

Rotation - Physiological effects

Space medicine - Physiological stress

Vestibular apparatus - Stimulation effects

Acceleration - Physiological effects

L. C. Subj. Head.

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FOR ERRATA

AD 268 791

THE FOLLOWING PAGES ARE CHANGES

TO BASIC DOCUMENT

AD 268791

ERRATA TO: Kennedy, R., and Graybiel, A. Symptomatology during prolonged exposure in a constantly rotating environment at a velocity of one revolution per minute. BuMed Project MR005.13-6001 Subtask 1 Report No. 62 and NASA Order No. R-1: Pensacola, Fla.: Naval School of Aviation Medicine, 8 September 1961.

1). Page 14.

Table XIII. Insert RL and JL in heading.

	RL					JL				
	AM	PM	AM	PM	Post	AM	PM	AM	PM	Post

2). Page 16.

Table XIV. Change RP to RB.

3). Page 16.

Table XV. Insert column headings.

	AG				RB			
	Open		Closed		Open		Closed	
	R	L	R	L	R	L	R	L

4). Page 8.

2nd paragraph, 3rd line change "(PR)" to "(DK)".

END CHANGE PAGES